

CLAIMS

1. A diagnostic method, comprising:

estimating a temperature of a NOx-reducing catalyst
 5 based on a thermodynamic model of said NOx-reducing catalyst;

estimating a hydrocarbon conversion efficiency of said NOx-reducing catalyst based on said temperature estimate;
 and

10 estimating a parameter indicative of an age of said NOx-reducing catalyst based on said estimated hydrocarbon conversion efficiency of said catalyst.

2. The method as set forth in Claim 1 wherein said
 15 thermodynamic model of said NOx-reducing catalyst is described by the following equations:

$$\frac{d}{dt}(c_{\text{substrate}} m_{\text{cat}} T + c_{\text{gas}} m_{\text{gas}} T) = c_p W (T_{\text{in}} - T) + h_i A_{\text{ext}} (T_{\text{amb}} - T) + (W_{\text{HC}} \cdot f_{\text{burn}}(T) + f_{\text{rel}}(T) \cdot \text{HC}_{\text{st}}) \cdot Q_{\text{lh}} \quad (1)$$

$$\frac{d}{dt} \text{HC}_{\text{st}} = (1 - f_{\text{burn}}(T)) \cdot W_{\text{HC}} - f_{\text{rel}}(T) \cdot \text{HC}_{\text{st}} \quad (2)$$

wherein $c_{\text{substrate}}$ is a heat capacity of a NOx-reducing catalyst
 20 substrate, m_{cat} is a mass of said catalyst, c_{gas} is a heat capacity of the exhaust gas, m_{gas} is a mass of the exhaust gas in the catalyst, c_p is a heat capacity of air at constant pressure, W is a total exhaust flow into said catalyst, T_{in} is a temperature of an exhaust gas mixture
 25 entering said NOx-reducing catalyst, h_i is a convective heat transfer coefficient of said catalyst, A_{ext} is a catalyst area exposed to said exhaust gas mixture entering said catalyst, T_{amb} is an ambient temperature, W_{HC} is a hydrocarbon flow transported in said exhaust gas mixture,

$f_{burn}(T)$ is said hydrocarbon conversion efficiency of said catalyst, Q_{lhv} is a heat contained in a unit mass of fuel, $f_{rel}(T)$ is an amount of hydrocarbons released and subsequently oxidized, and HC_s is an amount of hydrocarbons stored in the catalyst.

3. The method as set forth in Claim 2 wherein said hydrocarbon conversion efficiency of said NOx-reducing catalyst is estimated by inverting said model in order to obtain an input from an output.

4. The method as set forth in Claim 1 wherein said NOx-reducing catalyst is an ALNC.

5. The method as set forth in Claim 1 wherein said NOx-reducing catalyst is an oxidation catalyst.

6. The method as set forth in Claim 1 further comprising providing an indication of catalyst degradation based on said parameter.

7. A diagnostic method for a NOx-reducing catalyst, comprising:

estimating a temperature of the NOx-reducing catalyst based on a thermodynamic model of the catalyst, wherein said model inputs comprise at least a catalyst hydrocarbon conversion efficiency and an amount of reductant stored in the catalyst; and

inverting said thermodynamic model to obtain a parameter indicative of a NOx-reducing catalyst age.

8. The method as set forth in Claim 7 wherein said NOx-reducing catalyst is an ALNC.

9. The method as set forth in Claim 7 wherein said NOx-reducing catalyst is an oxidation catalyst.

10. The method as set forth in Claim 7 wherein said reductant is hydrocarbon.

11. The method as set forth in Claim 10 wherein said thermodynamic model is described by the following equations:

10 (1)

$$\frac{d}{dt}(c_{\text{substrate}} m_{\text{cat}} T + c_{\text{gas}} m_{\text{gas}} T) = c_p W (T_{\text{in}} - T) + h_i A_{\text{ext}} (T_{\text{amb}} - T) + (W_{\text{HC}} \cdot f_{\text{burn}}(T) + f_{\text{rel}}(T) \cdot \text{HC}_{\text{st}}) \cdot Q_{\text{thv}}$$

$$\frac{d}{dt} \text{HC}_{\text{st}} = (1 - f_{\text{burn}}(T)) \cdot W_{\text{HC}} - f_{\text{rel}}(T) \cdot \text{HC}_{\text{st}}$$

wherein $c_{\text{substrate}}$ is a heat capacity of a NOx-reducing catalyst substrate, m_{cat} is a mass of said catalyst, c_{gas} is a heat capacity of the exhaust gas, m_{gas} is a mass of the exhaust gas in the catalyst, c_p is a heat capacity of air at constant pressure, W is a total exhaust flow into said catalyst, T_{in} is a temperature of an exhaust gas mixture entering said NOx-reducing catalyst, h_i is a convective heat transfer coefficient of said catalyst, A_{ext} is a catalyst area exposed to said exhaust gas mixture entering said catalyst, T_{amb} is an ambient temperature, W_{HC} is a hydrocarbon flow transported in said exhaust gas mixture, $f_{\text{burn}}(T)$ is said hydrocarbon conversion efficiency of said catalyst, Q_{thv} is a heat contained in a unit mass of fuel, $f_{\text{rel}}(T)$ is an amount of hydrocarbons released and subsequently oxidized, and HC_{st} is an amount of hydrocarbons stored in the catalyst.

12. The method as set forth in Claim 10 further comprising providing an indication of catalyst degradation based on said parameter.

5 13. A method for diagnosing degradation of a NOx-reducing catalyst coupled downstream of an engine, the method comprising:

 estimating a hydrocarbon conversion efficiency of the catalyst based on a thermodynamic model;

10 estimating the exotherm based on said hydrocarbon conversion efficiency of the catalyst and on a total amount of hydrocarbon available for combustion in the catalyst, wherein said total available amount of hydrocarbon comprises an amount of hydrocarbon injected in the catalyst
15 in an engine exhaust gas mixture and a fraction of an amount of hydrocarbon stored in the catalyst.

 14. A method for estimating a parameter indicative of an age of a NOx-reducing catalyst based on a thermodynamic
20 model of the catalyst, wherein said thermodynamic model uses at least said parameter and an amount of reductant stored in the catalyst as inputs.

 15. The method as set forth in Claim 14 further
25 comprising providing an indication of catalyst degradation based on a comparison of said parameter to a nominal value.

 16. The method as set forth in Claim 15 wherein said
 estimating is performed when a temperature of said catalyst
30 is above light-off.

17. A diagnostic system, comprising:
an internal combustion engine;
a NOx-reducing catalyst coupled downstream of said
5 engine; and
a computer storage medium having a computer program
encoded therein, comprising:
code for estimating a temperature of said NOx-
reducing catalyst based on a thermodynamic
10 model of said NOx-reducing catalyst;
code for estimating a hydrocarbon conversion
efficiency of said NOx-reducing catalyst
based on said temperature estimate; and
code for estimating a parameter indicative of an
15 age of said NOx-reducing catalyst based on
said estimated hydrocarbon conversion
efficiency of said catalyst.

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